

## **Concrete, Mortars and Specialty Chemicals for Shotcrete Applications**

### **Introduction**

The Batimix range of products includes a number of dry mix ready to use concrete and mortar products for shotcreting applications for new construction, repair and rehabilitation works, specialty chemicals as well as shotcrete admixtures for the preparation of on-site concrete and mortar mixes.

Shotcreting is the projection at a high velocity onto a surface of concrete or sometimes mortar. A nozzle man applies the concrete or mortar from a pressurized hose. Shotcrete undergoes placement and compaction at the same time due to the force with which it is projected from the nozzle. The projected material encompasses the reinforcement forming structural shapes that include walls, floors, roofs, and other assemblies. Typical shotcrete applications include:

- Architectural rehabilitation and design works
- Rehabilitation of different kinds of structures such as bridges and dams.
- Repair works
- Construction of swimming pools, water parks and skateboard parks.
- Slope stabilization and channel / irrigation linings
- Temporary and final rock support
- Surface and underground mining
- Tunneling projects.

Although shotcrete uses all the components typically found in different types and applications of concrete, it is cast in a unique and special way. The dry mix and wet mix processes are the two application methods used, with the former still dominant in a large number of countries

In the dry process, the material consisting of cement and aggregates must be either dry or pre-dampened with a maximum 8% humidity. It is pushed / conveyed by air through a hose. At the nozzle, it is mixed with the water and, if required, a liquid accelerator. This liquid is transformed within a split second into concrete and projected under high velocity onto the surface. The operator adjusts the water cement ratio (W/C) to achieve a desired mortar consistency, by controlling the addition of the mixing water at the nozzle. Shotcrete applications are done in layers until the desired thickness is achieved.

In the wet mixed method, wet mixed concrete is conveyed either by a piston pump or by a rotor stator. At the nozzle, the accelerator and air are introduced. The air breaks the concrete into small particles projecting them onto the substrate. To minimize the rebound effect, wet-mix shotcrete is always applied with the aid of a set accelerator.

A comparative analysis of the two different shotcrete methods outlined above is as follows:

*A) Advantages:*

The dry-mix process offers amongst others the following advantages:

- Long conveying distances of up to 300 m horizontally and 100 m vertically.
- Long working time as the material does not set in the hose before it meets the water at the nozzle.
- High compaction and consolidation of the sprayed material due to the high velocity under which it is projected onto the surface.
- The pumps and hoses can be easily cleaned by air. No water is required and no mixed concrete has to be dealt with.
- Reasonable dispensing equipment cost.

The wet-mix process offers amongst others the following advantages:

- Accurate blending and dosage of all the components including water under operator's control. A complete and thorough cement hydration yields enhanced performances.
- Less rebound by around 15 to 20% compared to dry-mix spraying.
- The method does not require the same level of operator's skills as the dry mix process.
- Easier use of steel fibers and new admixture technology for large volume applications and high strength concrete requirements.

*B) Limitations:*

The dry-mix process has the following limitations:

- The permanent adjustment of the mixing water can lead to inconsistent concrete quality.
- Dry applied shotcrete can be relatively hard and stiff and not appropriate for some finishing operations.
- Limited use in interior applications in narrow and confined areas particularly without ventilation because of potential dust problems.
- The rebound factor can range from 20 to 40% depending on the application, type of material, and operator's skills.
- Lower production capacity of up to 7 m<sup>3</sup> per hour as compared to around 20 m<sup>3</sup> per hour with the wet mixed method.

The dry mix process offers the following limitations:

- Difficult and rather messy clean-up of the equipment and washed out concrete.
- Limited open time in the hose as the hydration process and concrete setting start promptly after the addition of water.
- Practical limitations in the conveying distance which should not exceed around 100 m horizontally and 50 m vertically.
- Wet mix equipment is normally more expensive, larger in size and thus harder to maneuver on the job site.

## **Admixtures used for shotcrete applications**

ASTM C1141 covers materials proposed for use as admixtures to be added to a Portland-cement shotcrete mixture for the purpose of altering the properties of the mixture. Admixture Types and Grades, classified as per ASTM and used in either one of the two processes are described herein:

### Type I - Dry mix shotcrete

- Grade 1 - Accelerating admixture, conventional - (ASTM D98, C494 Type C or E)
- Grade 2 - Retarding admixture - (ASTM C494 Type B or D)
- Grade 3 - Pozzolanic admixture - (ASTM C618, C989, C1240)
- Grade 4 - Metallic iron admixture - Not established
- Grade 5 - Coloring admixtures - (ATM C979)
- Grade 6 - Organic polymer admixtures - (ASTM C1438)
- Grade 7 - Not applicable
- Grade 8 - Not applicable
- Grade 9 - Accelerating Admixture - Quick setting - (ASTM C1102)

### Type II – Wet mix shotcrete

- Grade 1 - Accelerating admixture, conventional - (ASTM D98, C494 Type C or E)
- Grade 2 - Retarding Admixture - (ASTM C494 – Type B, D, or G)
- Grade 3 - Pozzolanic admixture - (ASTM C618, C989, C1240)
- Grade 4 - Metallic iron admixture - Not established
- Grade 5 - Coloring admixture - (ASTM C979)
- Grade 6 - Organic polymer admixture - (ASTM C1438)
- Grade 7 - Water reducing admixture - (ASTM C494 Type A, D, E, F, or G)
- Grade 8 - Air entraining admixture - (ASTM C260)
- Grade 9 - Accelerating admixture - Quick setting - (ASTM C1102)

Each of the above grades is further classified according to the following classes:

- Class A - Liquid
- Class B - Non-liquid

The Batimix range of admixtures for shotcrete includes the following:

### **Shotcrete Accelerating Admixtures**

Conventional shotcrete accelerating admixtures help the mix gel by reacting with the water. Dosage can be adjusted to optimize setting characteristics for different environments. While minimizing particle rebound, they are not designed to significantly accelerate concrete setting times to allow workers to finish concrete placing.

**Batimix Acc DG1-L** is a Type I Grade 1 Class A admixture.

**Batimix Acc DG1-P** is a Type I Grade 1 Class B admixture.

**Batimix Acc WG1-L** is a Type II Grade 1 Class A admixture.

**Batimix Acc WG1-P** is a Type II Grade 2 Class B admixture.

Quick setting shotcrete accelerating concrete admixtures minimize particle rebound and are intended for applications requiring quick setting within minutes such as may be required in tunneling and mining operations.

**Batimix Acc DG9-L** is a Type I Grade 9 Class A admixture.

**Batimix Acc DG9-P** is a Type I Grade 9 Class B admixture.

**Batimix Acc WG9-L** is a Type II Grade 9 Class A admixture.

**Batimix Acc WG9-P** is a Type II Grade 9 Class B admixture.

### **Shotcrete Retarding Admixtures**

Set retarding admixtures can be added to wet shotcrete mixes to allow for longer transport distances. They will lengthen setting times so as to allow for traffic, longer transport distances and hot climates. These are also designed to enhance the flow characteristics of shotcrete mixes particularly when using fibers and for reducing the pumping pressure of shotcrete mixes.

**Batimix Ret DG2-L** is a Type I Grade 2 Class A admixture.

**Batimix Ret DG2-P** is a Type I Grade 2 Class B admixture.

**Batimix Ret WG2-L** is a Type II Grade 2 Class A admixture.

**Batimix Ret WG2-P** is a Type II Grade 2 Class B admixture.

### **Pozzolanic Admixtures**

Silica fume, fly ash and slag are often added in different proportions in wet and dry mixes to the shotcrete mix to enhance strength and durability and reduce permeability of the hardened concrete.

**Batimix Silica Fume DG3-P** is a ready to use powdered microsilica (silica fume) meeting the requirements of Type I Grade 3 Class B admixtures (ASTM C1240).

**Batimix Fly Ash DG3-P** is a ready to use powdered fly ash meeting the requirements of Type I Grade 3 Class B admixtures (ASTM C618).

**Batimix Slag DG3-P** is a powdered slag meeting the requirements of Type I Grade 3 Class B admixtures (ASTM C989).

## Metallic Iron Admixtures

Metallic Iron admixtures are carefully graded ground metallic particles free from rust, oil, foreign materials and non-ferrous metal particles.

**Batimix Metallic Iron DG4-P** is a Type I Grade 4 Class B admixture.

**Batimix Metallic Iron WG4-P** is a Type II Grade 4 Class B admixture.

## Synthetic Structural Fibers

ASTM C1116 classifies fiber-reinforced concrete or shotcrete by the material type of the fiber incorporated. The performance of a fiber-reinforced concrete or shotcrete depends strongly upon the susceptibility of the fibers to physical damage during the mixing or shotcreting process, their chemical compatibility with the normally alkaline environment of the cement paste, and their resistance to service conditions encountered within uncracked concrete or as a consequence of cracking.

**Batimix Fibers Type I** is a Type I steel fiber. It contains stainless steel, alloy steel, or carbon steel fibers.

**Batimix Fibers Type II** is a Type II glass fiber. It contains alkali-resistant glass fibers.

**Batimix Fibers Type III** is a Type III synthetic fiber. It contains virgin polypropylene or other synthetic fibers.

## Coloring Admixtures

Coloring shotcrete admixtures (**Batimix Shot-Color**) are mixes based on various pigments. A limited range of standard colors is available. Different colors can also be provided upon request. Users should be aware that shades might vary.

## Organic Polymers

Bonding admixtures based on organic polymers or based on latex are used to create higher tensile strength and greater durability of polymer-modified shotcrete. Polymer modifiers are classified as per ASTM C1438 into two product types:

Type I – For use in areas not exposed to moisture

Type II – For general use

The range of Batimix bonding admixtures include the following polymers:

**Batimix PVA Type I.** It is a Type I PVA based polymer modifier.

**Batimix Acrylic Type II.** It is an acrylic based Type II polymer modifier.

**Batimix Versatic Type II.** It is a Type II versatic based polymer modifier.

**Batimix SBR Type II** is an SBR base Type II polymer modifier.

### **Flow Enhancement Admixtures**

Flow enhancement admixtures are high range water reducers that significantly enhance gravity flow and ease the pumping pressure of the shotcrete mix. While essential when using structural fibers in a mix, they greatly contribute in increasing the slump of a shotcrete mix without the addition of water.

**Batimix HWR WG7-L** is a Type II Grade 7 Class A admixture.

**Batimix HWR WG7-P** is a Type II Grade 7 Class B admixture.

**Batimix HWR WG7-V1** is a high range water reducer that can be used to pump concrete over long distances. It can be used to flow shotcrete vertically without segregation.

**Batimix HWR WG7-V2** is a lubricant that will ease the movement of cement and aggregate particles within the mix to aid in concrete pumping.

### **Air-Entraining Admixtures**

Air entraining agents are often added to shotcrete mix designs for flowability and most especially freeze / thaw protection. ASTM C1141 defines the shotcrete air-entraining admixture requirements, which like concrete admixtures must conform to ASTM C260 requirements.

**Batimix Air WG8-L** is a Type II Grade 8 Class A admixture.

**Batimix Air WG8-P** is a Type II Grade 8 Class B admixture.

### **Dry- Mix Line of Premium Products**

ASTM C1480 provides the standard specification for packaged, pre-blended, dry combined mix of materials for use in wet or dry shotcrete applications. The products supplied are characterized by type and grade and delivered to customers with the ingredients uniformly mixed. They are designed to significantly enhance the performance of shotcrete applications and are specifically formulated to generate less dust in dry mix processes and reduce the rebound factor whether used in dry or wet applications.

Shotcrete Types are based on aggregate use:

- Type FA shotcrete shall contain aggregate in accordance with the requirements of Specification C1436 Grading # 1. Aggregates failing to comply with Grading # 1 can be used if preconstruction testing proves that they give satisfactory results.
- Type CA shotcrete shall contain coarse and fine aggregates in accordance with the requirements of specification C1436 Grading # 2. Aggregates failing to comply with Grading # 2 can be used only if preconstruction testing proves that they give satisfactory results or if acceptable service records exist.

Shotcrete Grades are based on the desired physical properties of the material:

- Grade GR shotcrete is a general use product
- Grade SR shotcrete has sulfate resistance
- Grade LP shotcrete has permeability values
- Grade FR Class I shotcrete incorporating fibers is intended to minimize plastic shrinkage cracking
- Grade FR Class II shotcrete incorporating fibers is intended to provide a minimum level of post-crack flexural load capacity for hardened shotcrete

It is to be noted that a single material may meet more than one grade. The purchaser may specify other properties. The range of Batimix dry, packaged and pre-blended products for use in wet or dry shotcrete applications includes the following:

**Batimix Concrete 560** is a shotcrete mix for dry process applications conforming to the requirements of ASTM C1480 Type CA Grade GU (general use).

**Batimix Concrete 561** is a shotcrete mix for dry process applications conforming to the requirements of ASTM C1480 Type CA Grade SR (sulfate resistant).

**Batimix Concrete 562** is shotcrete mix for dry process applications conforming to the requirements of ASTM C1480 Type CA Grade LP (lower permeability).

**Batimix Concrete 563** is a shotcrete mix for dry process applications conforming to the requirements of ASTM C1480 Type CA Grade FR Class I (fiber reinforcement).

**Batimix Concrete 564** is a shotcrete mix for dry process applications conforming to the requirements of ASTM C1480 Type CA Grade FR Class II (fiber reinforcement).

**Batimix Concrete 580** is a shotcrete mix for wet process applications conforming to the requirements of ASTM C1480 Type CA Grade GU (general use).

**Batimix Concrete 581** is a shotcrete mix for wet process applications conforming to the requirements of ASTM C1480 Type CA Grade SR (sulfate resistant).

**Batimix Concrete 582** is a shotcrete mix for wet process applications conforming to the requirements of ASTM C1480 Type CA Grade LP (lower permeability).

**Batimix Concrete 583** is a shotcrete mix for wet process applications conforming to the requirements of ASTM C1480 Type CA Grade FR Class I (fiber reinforcement).

**Batimix Concrete 584** is a shotcrete mix for wet process applications conforming to the requirements of ASTM C1480 Type CA Grade FR Class II (fiber reinforcement).

**Batimix Mortar 660** is a shotcrete mortar for dry process applications conforming to the requirements of ASTM C1480 Type FA Grade GU (general use).

**Batimix Mortar 661** is a shotcrete mortar for dry process applications conforming to the requirements of ASTM C1480 Type FA Grade SR (sulfate resistant).



**Batimix Mortar 662** is a shotcrete mortar for dry process applications conforming to the requirements of ASTM C1480 Type FA Grade LP (lower permeability).

**Batimix Mortar 663** is a shotcrete mortar for dry process applications conforming to the requirements of ASTM C1480 Type FA Grade FR Class I (fiber reinforcements).

**Batimix Mortar 664** is a shotcrete mortar for dry process applications conforming to the requirements of ASTM C1480 Type FA Grade FR Class II (fiber reinforcement).

**Batimix Mortar 680** is a shotcrete mortar for wet process applications conforming to the requirements of ASTM C1480 Type FA Grade GU (general use).

**Batimix Mortar 681** is a shotcrete mortar for wet process applications conforming to the requirements of ASTM C1480 Type FA Grade SR (sulfate resistant).

**Batimix Mortar 682** is a shotcrete mortar for wet process applications conforming to the requirements of ASTM C1480 Type FA Grade LP (lower permeability).

**Batimix Mortar 683** is a shotcrete mortar for wet process applications conforming to the requirements of ASTM C1480 Type FA Grade FR Class I (fiber reinforcement).

**Batimix Mortar 684** is a shotcrete mortar for wet process applications conforming to the requirements of ASTM C1480 Type FA Grade FR Class II (fiber reinforcement).

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